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Synthesis and Design of Thermochemical and Biochemical Biomass Processing Networks under Uncertainty

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Processing and chemical industries traditionally rely on fossil based feedstock, a limited resource. Coupled with increasing energy demands and environmental and climate effects, it motivates the development of new and more sustainable technologies for processing renewable feedstocks, with the aim of bridging the gap for fuel, chemical and material production. This contribution is focusing on biorefinery network design and, in particular, on the development of integrated-intensified chemical/biochemical processes under uncertainty. In a typical biorefinery, the systems generally operate by processing a bio-based feedstock to produce various products such as fuel, chemicals and/or power/heat. As there are several feedstock sources, as well as many alternative conversion technologies to choose from to match a range of products, this creates a number of potential processing paths for biorefinery development. Therefore, in the early stage of planning and design, it is important to identify the optimal biorefinery processing path with respect to economics, technical feasibility and consumption of resources. One of the challenges in identifying an optimal biorefinery network is the uncertainty in the data regarding availability of renewable feedstock, its composition, technical performance of alternative processing technologies and future markets for products (price, etc) among others. Hence formal uncertainty analysis is important if not essential, since it provides additional information that is helpful for robust decision-making during the early stage conceptual design .

During earlier work in our research group [(1,2)], a methodology to identify/generate optimal biorefineries was developed, however with focus only on bio-based conversion routes. The methodology consists of tools and methods including databases, models, superstructure, and solution strategies to represent, describe and evaluate various combinations of processing networks. The optimization of the network is formulated as a mixed integer nonlinear programming type of problem and solved in GAMS. The methodology was applied both for designing optimal biorefinery networks considering biochemical routes, [2] as well as for food processing networks [1].

In this study, we expand the scope and the size of the biorefinery network problem by extending the database, the models and the superstructure of the methodology with thermo-chemical biomass conversion routes: the conversion of biomass feedstocks (corn stover, poplar wood) to fuels and chemicals (FT-gasoline, FT-diesel, bioethanol and higher alcohols) via thermal decomposition processes (pyrolysis, gasification). In addition, sensitivity and uncertainty analysis are performed. Appropriate ranges for uncertain parameters are selected, and Latin hypercube sampling is used to sample parameters from their respective domain of uncertainty [3]. Then, MINLP optimization and Monte Carlo simulation are performed to find the optimal processing path under uncertainy.

The expanded database and superstructure with uncertainty analysis form a powerful process synthesis toolbox to be used in design of future biorefineries with respect to technical, economic and environmental optimization criteria.

Reference:

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[3] Sin G., Gernaey K.V., Lantz A.E.. (2009). *Biotechnology Progress*, 25, 1043-1053.